PCMCIA: The Expansion System of the Future

BY WINN ROSCH

Even as the debate over Micro Channel, EISA, ISA, and VESA local bus rages, another challenger is quietly gaining momentum as the best choice for future expansion needs. Called the PC Card, this new entrant is not simply a bus. Rather, it incorporates an entire connection architecture within the thickness of a credit card.

Conceived as a way to add expansion capabilities to subnotebook-size computers, the versatile design of the PC Card will make it at home in almost anything electronic, from CAD workstations to auto-everything cameras. Someday you may even find a PC Card lurking in your toaster oven or your music synthesizer.

Such dramatic predictions reflect the virtues and versatility of the underlying standard, and the features of the PC Card design read like a wish list for the expansion standard of the future. PC Cards are compatible with all of the old buses you've grown to know and hate—ISA, Micro Channel, EISA, or what have you. Because they're operating system and device independent, you can plug the same PC Card peripheral into a PC, Mac, Newton, or whatever the next generation holds in store. The PC Card system is self-configuring, so you won't have to deal with DIP switches, fiddle with jumpers, or search for a Reference Diskette again. The design is so robust that you can insert or remove a PC Card with the power on without worrying that you'll damage it, your PC, or data stored on the card. The PC Card standard is even ready for tomorrow's battery-saving low-voltage computer designs.

One key to its success is that the PC Card is not a proprietary standard foisted on the industry by a single company or small coterie. The design is the product of a group called the Personal Computer Memory Card International Association (PCMCIA), which has more than 220 members involved in all aspects of the computer and electronics industry. The PCMCIA standard is completely open, and all specifications are available to anyone requesting them from the organization. (The charge for the latest specification release was not set at the time of this writing, but it is estimated at between $200 to $300. For further information, contact PCMCIA at 1030G E. Duane Ave., Sunnyvale, CA 94086; 408-720-0107; fax, 408-720-9416.)

Originally designed for notebook-size and smaller PCs, PC Cards offer a whole new interconnection architecture that's compatible with current and future buses.

Rather than operate completely independently, PCMCIA cooperates with other standard-setting organizations. Thus, for example, by working jointly with the Japan Electronic Industry Development Association (JEIDA) in December 1989, PCMCIA was able to ensure that the standards it developed would be truly international in scope. Today each organization sends a delegation to the meetings of the other.

Although initially intended simply to add programs to miniature computers that lacked disk drives, in the last year or so PC Cards have grown to embrace a full repertoire of expansion functions. Besides memory and firmware, high-speed modems and hard disks have been encapsulated into PC Cards. In coming months you can expect to find nearly anything that fits on a PC expansion board downsized to squeeze into a PC Card.

To bring you up to date on this exciting new development, this Lab Notes will look at what PC Cards are, where the idea came from, how they work, and what their potential is for you and your PC.

GIVING THE CARD CREDIT Memory on a credit card–size plug-in board long predates the creation of PCMCIA. As early as 1984 such memory cards served as a means of providing the ROM to store fonts for laser printers. By 1987, memory manufacturers were packaging expansion RAM in similar packages for notebook computers.

The memory-card industry leader at that time was Mitsubishi, whose memory cards used a proprietary 60-pin package. Fujitsu Microelectronics had a similar, competing line of memory cards and "smart cards" (Fujitsu's term for any small card with integrated circuits on it), but these were based on a 68-pin connector design.

John Reimer, now vice president of marketing for SUNDISK and chairman of PCMCIA, was appointed marketing manager for microcomputer products at Fujitsu in 1987. He quickly determined that he had inherited what amounted to a product looking for a purpose. It seemed to Reimer that card memory had the potential to serve as a data exchange medium that lacked the environmental vulnerability of floppy disks (such as dust, temperature, shock, and impact).

While exploring marketing opportunities for his memory cards, Reimer discovered that the Poqet Computer Company was itself investigating the use of memory cards as an alternative to disk

drives for a new product that was ultimately to become the first true subnotebook PC. (Fujitsu had invested in the Poqet startup and has since acquired the company.) But Poqet was so concerned about the lack of standards among the various memory cards that it hesitated to select a memory card product because of uncertainty about which designs would succeed.

Sensible as was Poqet's desire to standardize memory cards throughout the industry, Reimer found that realizing the desire was a practical impossibility. No single standards organization was set up to rule on all the required aspects of such a design: physical card size, number and function of the connector pins, data file formats, and software interface. And to run the different facets of a card design through the whole gamut of separate standards sanctioning organizations might take longer than the useful life of the product!

While promoting the idea that the personal computer industry should itself develop a memory card standard, Reimer discovered that Lotus Development was contemplating putting its software on ROM cards. Lotus had been among the first to embrace putting software on the larger cartridges of the ill-fated PC*jr*. But Lotus, too, balked at the prospect of a profusion of incompatible card designs, and offered its support when Reimer proposed to bring parties interested in memory card standardization together. Reimer found enough initial support among other major suppliers of software, semiconductors, and personal computers, to convene a meeting of representatives from about 25 manufacturers that took place at the Fairmont Hotel in San Jose in June 1988.

That first informal meeting pointed out the possibilities—including the potential for an antitrust suit. So with $10,000 contributed by Fujitsu, Reimer hired lawyers to draft guidelines that would avert legal tangles and organized the group that became PCMCIA. At that early point, however, the role and future of the organization were uncertain. Early on, Reimer entertained the possibility that PCMCIA would craft a standard and quietly fade away, mission accomplished. But the organization gained its own momentum at its monthly meetings, and the standard expanded in scope from a PC enhancement to a universal digital data exchange mechanism.

PC Card, Release 1.0, the first generation of the PCMCIA standard, was introduced in September 1990. It contemplated only the use of solid-state memory on the card as a means of data storage. But the PC Card intrigued both the makers of subnotebook computers and peripheral developers, who believed that the standard could be expanded to incorporate I/O devices as well as memory.

As a result, the PC Card standard was updated in September 1991 to comprise a more generalized interface that would accommodate both storage and input/output devices. Additionally, the new Release 2.0 standard allowed the use of thicker cards, permitting the incorporation of a wider variety of semiconductor circuits. It also allowed programs stored on PC Cards to be executed in the card memory rather than requiring the code to be downloaded into standard RAM.

In keeping with good practice, backward compatibility was maintained: Cards designed under PCMCIA Release 1.0 will plug into and work in Release 2.0 machines. Because Release 2.0 adds a wealth of features that older hardware may not understand, however, all the functions of a new card may not work in an older system. Because normal thickness cards of both generations are physically the same, new cards will fit slots in old systems. No combination of card and system will result in damage at either end of the connection.

Backward compatibility at that early stage was, of course, practically a nonissue. The only device limited solely to PCMCIA Release 1.0 form factor slots was the Poqet subnotebook. Although the Hewlett-Packard 95LX conforms to Release 1.0 electrically, its socket accommodates the thicker cards permitted by Release 2.0.

The completed PCMCIA 2.0 is much more than a simple set of physical specifications for card dimensions and a bus pinout. The standard also describes file formats and data structures; a method through which a card can convey its configuration and capabilities to its host, a device-independent means of accessing card hardware; and software links independent of operating systems.

The PCMCIA Expansion System

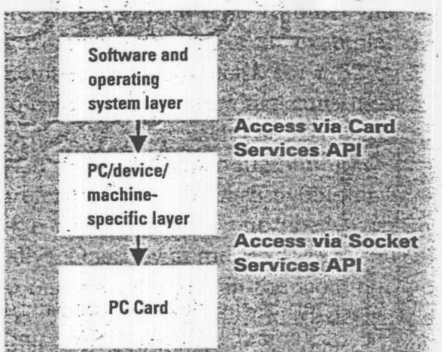

***Figure 1:* PCMCIA includes not only a computer and host-independent socket for the PC Cards but also program calls that link software into the PCMCIA system.**

ARCHITECTURAL OVERVIEW At first glance, PCMCIA 2.0 looks a bit archaic as an expansion bus. It provides only a 16-bit interface; it lacks such advanced features as bus mastering; and it offers but a single interrupt request (IRQ) line. However, because the versatile design of PCMCIA is fundamentally different from that of ordinary expansion buses, any such shortcomings are but temporary. (PCMCIA is working on support for bus-mastering adapters, for example.)

PCMCIA's expansion system is not a simple extension to the bus circuitry of a computer. Rather, it is a system that includes everything from a computer and host-independent socket for the PC Cards to program calls that link software into the PCMCIA system. Figure 1 shows an overview of the PCMCIA expansion system.

A hardware device supporting the PCMCIA standard can have from one to 255 PCMCIA *adapters*; that is, circuits that match the signals of PC Cards to the host. Up to 16 separate PC Card sockets can be connected to each adapter, much as you can connect two hard disks to an IDE controller or seven devices to a SCSI host adapter. Consequently, PCMCIA 2.0 allows for the possibility of plugging up to 4,080 PC Cards into one system.

The memory and I/O registers of each PC Card are individually mapped into the address range of the host device. Thus the addresses on the card need not be identical with those of the host. The host accesses the PC Card resources through one or more *windows*, which are memory

direction (positive terminal up).

In addition to the physical measures that facilitate getting the cards into their sockets, two pins—one on each side of the connector—allow the PC host to determine whether the card is properly seated. If the signal (ground) from one is present and the other is not, the system knows that the card is skewed or that it is otherwise improperly inserted in the connector.

Although the PCMCIA standard allows for only 16 data lines, the specification is flexible enough to allow for multiplexed 32-bit operation in custom designs.

The one part of the PC Card that has not yet been standardized is the rear edge, where connections are made to communications products such as modems. PCMCIA is currently working on this area and hopes to develop specifications for the connectors and their placement.

PLUGGING IN All types of PC Cards use the same 68-pin connector, whose contacts are arranged in two parallel rows of 34 pins. The lines are spaced at 1.27 mm (0.050 inch) intervals between rows and between adjacent pins in the same row. Male pins on the card engage a single molded socket on the host.

To insure proper powering up of the card, the pins are arranged so that the power and ground connections are longer (3.6 mm) than the signal leads (3.2 mm). Because of their greater length, therefore, power leads engage first so that potentially damaging signals will not be applied to unpowered circuits. The two pins (36 and 67) that signal that the card has been inserted all the way are shorter (2.6 mm) than the signal leads.

As we saw earlier, the standard PCMCIA 2.0 connector itself allows for two PC Card variations: memory-only (which essentially conforms to the Release 1.0 standard) and I/O cards. Figure 3 lists the pin assignments. All but 10 pins of the standard 68 share common functions between the two card styles (these are designated in the table with asterisks). Four memory card signals are differently defined for I/O cards (pins 16, 33, 62, and 63); three memory card signals are modified for I/O functions (pins 18, 52, and 61); and three pins reserved on memory cards are used by I/O cards (pins 44, 45, and 60).

When a PC Card is plugged into a slot, the host computer's PCMCIA adapter circuitry initially assumes that it is a memory card. The card defines itself as an I/O card through its on-board CIS data, which the host computer reads upon initializing the PC Card.

The PCMCIA 2.0 standard allows for card implementations that use either 8- or 16-bit data buses. In memory operations, two Card Enable signals (pins 7 and 42) set the bus width; pin 7 enables even-numbered address bytes and 42 enables odd bytes. All bytes can be read by an 8-bit system by activating pin 7 but not 42 and toggling the lowest address line (A0, pin 29) to step to the next byte.

Although the current PCMCIA standard allows for only 16 data lines, the specification is flexible enough to allow for multiplexed 32-bit operation in custom designs. Properly implemented, such a card would work with a standard 16-bit interface in devices that comply with Release 2.0, but it could gain full 32-bit power in machines matched to a proprietary enhancement of the standard. PCMCIA is discussing a 32-bit extension to the PC Card design, but as yet no timetable has been set for developing it.

Twenty-six address lines are used, allowing the direct addressing of up to 64MB of data. The memory areas on each card are independent. That is, each PC Card can define its own 64MB address range as its Common Memory. Not all of this memory range is directly addressable by some hosts: 8088-based systems are limited by their microprocessors to 1MB of directly addressed memory, for example. The entire 64MB range can be addressed by such systems through a PCMCIA window, however.

In addition to Common Memory, each card has a second 64MB address space devoted to the Attribute Memory that holds the card's setup information. The entire range need not have physical memory associated with it. In fact, most PC Cards will likely devote only a few kilobytes of the available addressing range to CIS storage.

Activating the Register Select signal (pin 61) shifts the 26 address lines normally used to address Common Memory to specifying locations in Attribute Memory instead. The address space assigned to Attribute Memory need not correspond to a block of memory separate from Common Memory. To avoid the need for two distinct memory systems, a PC Card can be designed so that activating the Register Select signal simply points to a block of Common Memory devoted to storing setup information. All

Memory-Only Card Interface

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PIN	SIGNAL	I/O	FUNCTION	+/-
1	GND		Ground	
2	D3	I/O	Data bit 3	
3	D4	I/O	Data bit 4	
4	D5	I/O	Data bit 5	
5	D6	I/O	Data bit 6	
6	D7	I/O	Data bit 7	
7	CE1	I	Card Enable	-
8	A10	I	Address bit 10	
9	OE	I	Output Enable	-
10	A11	I	Address bit 11	
11	A9	I	Address bit 9	
12	A8	I	Address bit 8	
13	A13	I	Address bit 13	
14	A14	I	Address bit 14	
15	WE/PGM	I	Write Enable	-
16*	RDY/BSY	O	Ready/Busy	+/-
17	Vcc			
18*	Vpp1		Programming Supply Voltage 1	
19	A16	I	Address bit 16	
20	A15	I	Address bit 15	
21	A12	I	Address bit 12	
22	A7	I	Address bit 7	
23	A6	I	Address bit 6	
24	A5	I	Address bit 5	
25	A4	I	Address bit 4	
26	A3	I	Address bit 3	
27	A2	I	Address bit 2	

Figure 3: **These are the pin assignments for a memory card. Asterisks indicate the 10 assignments that differ between memory cards and I/O cards. Active "low" signals are shown by a - (minus sign); active "high" signals are shown by a + (plus sign).**

Memory-Only Card Interface

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PIN	SIGNAL	I/O	FUNCTION	+/-
28	A1	I	Address bit 1	
29	A0	I	Address bit 0	
30	D0	I/O	Data bit 0	
31	D1	I/O	Data bit 1	
32	D2	I/O	Data bit 2	
33*	WP	O	Write protect	+
34	GND		Ground	
35	GND		Ground	
36	CD1	O	Card detect	-
37	D11	I/O	Data bit 11	
38	D12	I/O	Data bit 12	
39	D13	I/O	Data bit 13	
40	D14	I/O	Data bit 14	
41	D15	I/O	Data bit 15	
42	CE2	I	Card Enable	-
43	RFSH	I	Refresh	
44*	RFU		Reserved	
45*	RFU		Reserved	
46	A17	I	Address bit 17	
47	A18	I	Address bit 18	
48	A19	I	Address bit 19	
49	A20	I	Address bit 20	
50	A21	I	Address bit 21	
51	Vcc			
52*	Vpp2		Programming Supply Voltage 2	
53	A22	I	Address bit 22	
54	A23	I	Address bit 23	
55	A24	I	Address bit 24	
56	A25	I	Address bit 25	
57	RFU		Reserved	
58	RESET	I	Card Reset	+
59	WAIT	O	Extend bus cycle	-
60*	RFU		Reserved	-
61*	REG	I	Register select	-
62*	BVD2	O	Battery voltage detect 2	
63*	BVD1	O	Battery voltage detect 1	
64	D8	I/O	Data bit 8	
65	D9	I/O	Data bit 9	
66	D10	I/O	Data bit 10	
67	CD2	O	Card detect	-
68	GND		Ground	-

PC Cards limit access to Attribute Memory to an 8-bit link using the eight least-significant data lines.

To open or close access to data read from a PC Card, the host computer activates a signal on the card's Output Enable line (pin 9). A Ready/Busy line (pin 16) on memory cards allows the card to signal when it is busy processing and cannot accept a data transfer operation. The same pin is used on I/O cards to make interrupt requests to the host system. During setup, however, an I/O card can redefine pin 16 back to its Ready/Busy function. Under Release 2.0, memory or I/O PC Cards can also delay the completion of an operation in progress—in effect, slowing the host to accommodate the time needs of the card—by activating an Extend Bus Cycle signal on pin 59.

The Write Protect pin (pin 33) relays the status of the write-protect switch on memory cards to the computer host. On I/O cards, this pin serves to indicate that a given I/O port has a 16-bit width.

Pins 62 and 63 on memory cards output two battery status signals. Pin 63 indicates the status of the battery: When activated, the battery is in good condition; when not activated, it indicates that the battery needs to be replaced. Pin 62 refines this to indicate that the battery level is sufficient to maintain card memory without errors; if this signal is not activated, it indicates that the integrity of on-card memory may already have been compromised by low battery power.

Memory cards that use EPROM memory often require higher than normal voltages to reprogram their chips. Pins 18 and 52 on the PCMCIA interface provide these voltages when needed.

The same 26 lines used for addressing Common and Attribute Memory serve as port selection addresses on I/O cards. Two pins, I/O read (44) and I/O write (45) signal that the address pins will be used for identifying ports and whether the operation is a read or a write.

Unlike memory addresses, however, the I/O facilities available to all PC Cards in a system share "only" one 67,108,864-byte (64MB) range of port addresses. Considering that the AT bus allows only 64K of I/O ports, of which some systems recognize a mere 16K, the shared port address space represents no real limitation. Even assigning 16K ports to each of the 4,080 possible PC Cards in a system would leave a few port addresses unused. Whether ports are 8- or 16-bit is indicated by the signal on pin 33.

I/O PC Cards each have a single interrupt request signal. The signal is mapped to one of the PC interrupt lines by the computer host. That's to say, the PC Card generates a generic interrupt and it is the host computer's responsibility to route the interrupt to the appropriate channel.

The PCMCIA specification requires all PC Cards to be able to generate edge-triggered (PC and AT-style) interrupts and level-sensitive interrupts (as used by Micro Channel and EISA in some modes). Every card conforms to the host's requirements.

An audio output line is also available from I/O PC Cards. This connection is not intended for high-quality sound, however, for it allows only binary digital (on/off) signals. The audio lines of all PC Cards in a system are linked together by an XOR (exclusive OR) logic gate that is fed to a single common loudspeaker.

PC Card, Release 2.0, adds a single Reset signal to all cards at pin 58. When the host computer activates this signal, the card returns to preinitialization settings, with I/O cards returning to their power-on memory card emulation.

PCMCIA 2.0 contemplates the use of PC Cards that operate at either the standard TTL 5-volt level or at a power-saving reduced voltage level of 3.3. The current standard requires that cards initialize operating at 5 volts then shift to lower voltage operation under the direction of the card's configuration information. PCMCIA is currently working on extending the standard to embrace PC Cards that operate solely at 3.3 volts.

Besides the efforts at extending PCMCIA to future technologies such as 32-bit data paths and bus mastering, PCMCIA is also developing standards for incorporating specific device types into the system. Already the group has fully described the needs for XIP, which allows programs to execute from their storage locations on PC Cards instead of needing to be loaded as if from disk into normal system RAM. PCMCIA has also developed standards for linking AT Attachment-style IDE hard disks into PC Card sockets.

As the storage and expansion needs of PCs and other electronic devices continue to evolve, the PCMCIA PC Card standard will likely follow in lockstep. Undoubtedly it's the PC expansion system of the future—and the first truly universal data interchange system. □

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